

# Comment on “Photon energy and carrier density dependence of spin dynamics in bulk CdTe crystal at room temperature”

J. H. Jiang and M. W. Wu\*

Hefei National Laboratory for Physical Sciences at Microscale and Department of Physics,  
University of Science and Technology of China, Hefei, Anhui, 230026, China  
(Dated: October 8, 2009)

We comment on the conclusion by Ma *et al.* [Appl. Phys. Lett. **94**, 241112 (2009)] that the Elliott-Yafet mechanism is more important than the D'yakonov-Perel' mechanism at high carrier density in intrinsic bulk CdTe at room temperature. We point out that the spin relaxation is solely from the D'yakonov-Perel' mechanism. The observed peak in the density dependence of spin relaxation time is exactly what we predicted in a recent work [Phys. Rev. B **79**, 125206 (2009)].

In a recent Letter,<sup>1</sup> Ma *et al.* measured the density dependence of electron spin relaxation time in intrinsic bulk CdTe at room temperature. They found that the electron spin lifetime first increases then decreases with increasing excitation density. They attributed the increase of spin lifetime at low excitation density to the D'yakonov-Perel' mechanism whereas the decrease at high excitation density to the Elliott-Yafet mechanism. They concluded that the Elliott-Yafet mechanism dominates spin relaxation at high excitation density in CdTe at room temperature.

Their conclusion can not be correct. As shown in our recent work, the Elliott-Yafet mechanism is unimportant even in narrow band gap semiconductors such as InAs and InSb for *n*-type and intrinsic samples in metallic regime.<sup>2</sup> For CdTe, which has a large band gap of  $E_g = 1.45$  eV, the Elliott-Yafet mechanism can not be important for intrinsic samples, especially at such high temperature of 300 K.

Below, through a fully microscopic calculation, we show that the Elliott-Yafet mechanism is totally *irrelevant* to spin relaxation under the experimental condition. The calculation is based on the fully microscopic kinetic spin Bloch equation approach with *all* relevant scatterings, such as electron-impurity, electron-phonon, electron-electron and electron-hole scatterings, explicitly included.<sup>2</sup> The spin-flip process due to the Elliott-Yafet mechanism is *fully* incorporated in *all* these scatterings. The calculation based on kinetic spin Bloch equation approach has achieved good agreements with different experiments [e.g., see Appendix A of Ref. 2].

The calculation of the spin relaxation due to the Elliott-Yafet mechanism is based on the following spin-flip scattering,

$$\Gamma_s(\mathbf{k}) = 2 \sum_{\mathbf{k}'} \frac{1}{\tau_p(\mathbf{k} \rightarrow \mathbf{k}')} |\Lambda_{\mathbf{k},\mathbf{k}'}^{\uparrow\downarrow}|^2 \quad (1)$$

where  $\frac{1}{\tau_p(\mathbf{k} \rightarrow \mathbf{k}')}$  is the momentum scattering rate from state  $\mathbf{k}$  to state  $\mathbf{k}'$  and  $\Lambda_{\mathbf{k},\mathbf{k}'}^{\uparrow\downarrow} = -i\lambda_c(\mathbf{k} \times \mathbf{k}') \cdot \boldsymbol{\sigma}^{\uparrow\downarrow}$ .<sup>3</sup> Here  $\lambda_c = \frac{\hbar^2 \eta(1-\eta/2)}{3m_c E_g(1-\eta/3)}$  with  $\eta = \frac{\Delta_{SO}}{\Delta_{SO} + E_g}$ .<sup>3</sup>  $m_c$  is the conduction band effective mass.  $E_g$  and  $\Delta_{SO}$  are the band-gap and the spin-orbit splitting of the valence band, respectively. The momentum scattering rate

is determined by *all* relevant scatterings, such as the electron-impurity, electron-phonon, electron-electron and electron-hole scatterings:  $\frac{1}{\tau_p} = \frac{1}{\tau_{ei}} + \frac{1}{\tau_{ep}} + \frac{1}{\tau_{ee}} + \frac{1}{\tau_{eh}}$ . The corresponding scatterings are given in detail in Ref. 2.

The spin relaxation time  $\tau_s$  is then obtained by average over  $\Gamma_s(\mathbf{k})$ ,  $1/\tau_s = \langle \Gamma_s(\mathbf{k}) \rangle$ . It is noted that there is *no fitting parameter* in the calculation. The material parameters of CdTe are taken from the standard handbooks of *Landolt-Börnstein*.<sup>4</sup>

From the parameter-free fully microscopic calculation, we obtain the spin lifetime limited by the Elliott-Yafet mechanism,  $\tau_s \gtrsim 800$  ps in the excitation density range of  $10^{14}$  to  $10^{17}$  cm<sup>-3</sup>. This is at least two-orders of magnitude larger than the one observed in the experiment by Ma *et al.*<sup>1</sup> Hence the Elliott-Yafet mechanism is totally *irrelevant* under the experimental condition. The spin relaxation is then solely determined by the D'yakonov-Perel' mechanism.

As we have pointed in a recent work,<sup>2</sup> the density dependence of spin relaxation time due to the D'yakonov-Perel' mechanism  $\tau_s \sim 1/[\langle \Omega(\mathbf{k})^2 \rangle \tau_p]$  is nonmonotonic in intrinsic bulk III-V semiconductors: spin relaxation time increases with increasing density in non-degenerate regime due to decrease of momentum scattering time  $\tau_p$  but decreases in degenerate regime due to the enhancement of inhomogeneous broadening  $\langle \Omega(\mathbf{k})^2 \rangle$ . There is a peak in the crossover regime. For II-VI semiconductors with zinc-blende structure, the spin-orbit coupling and the band structure is similar to III-V semiconductors. Hence the same behavior is also expected. Actually, the band and material parameters of CdTe are very similar to GaAs. In intrinsic GaAs at room temperature, the peak density is  $9 \times 10^{16}$  cm<sup>-3</sup>.<sup>2</sup> In the experiment by Ma *et al.*, the peak density is  $3 \times 10^{11}$  cm<sup>-2</sup>. As the authors did not determine the penetration depth of the laser, a rough estimation gives the peak density of  $6 \times 10^{16}$  cm<sup>-3</sup> which is close to the one in GaAs. This indicates that the observed peak in density dependence of spin lifetime should be similar to what we have predicted in III-V semiconductors.<sup>2</sup> However, due to the uncertainty in the penetration depth and the possible effect of hot-electron effect of the photo-excited carriers (as also indicated by the experimental results in the photon en-

ergy dependence), it is premature to give a quantitative comparison.

This work was supported by the Natural Science Foundation of China under Grant No. 10725417.

---

\* Author to whom correspondence should be addressed; Electronic address: mwwu@ustc.edu.cn.

<sup>1</sup> H. Ma, Z. Jin, G. Ma, W. Liu, and S. H. Tang, Appl. Phys. Lett. **94**, 241112 (2009).

<sup>2</sup> J. H. Jiang and M. W. Wu, Phys. Rev. B **79**, 125206 (2009).

<sup>3</sup> F. Meier and B. P. Zakharchenya, *Optical Orientation* (North-Holland, Amsterdam, 1984).

<sup>4</sup> *Semiconductors*, Landolt-Börnstein, New Series, Vol. 17b, ed. by O. Madelung (Springer-Verlag, Berlin, 1987).